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ABSTRACT

Technology contributes to the growth of human knowledge in five distinct, though overlapping, ways: (1) all technologies are material embodiments and thus more or less durable records of ideas that have survived some test with external reality; (2) telescopes, microscopes, and similar technologies extend external experience and knowledge to areas beyond human perception; (3) computers help people generate knowledge from otherwise overwhelming quantities of experiences; (4) the abstraction permitted by speech, writing, and similar media facilitate the evaluation and dissemination of knowledge; and (5) audiovisual media permit criticism and dissemination of relatively concrete representations of external reality. As the implementation of knowledge through technology significantly alters external reality, technology itself appears to play a decided role in our planet's evolutionary process. Neither human knowledge nor technology is free of unintended consequences, but they do inject an element of direction, deliberation, and planning into a naturally selective universe, which presumably previously had none. Through the expression of human knowledge in technology, the future of the universe lies in the human mind, and thus in the future technologies that assist it. (HOD)

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Evolution or the adaptation of organisms to environments can be seen as a process of knowledge accumulation, or the development of behaviors which reflect an understanding of the environment at least accurate enough for survival. Starting with the premise that the world is not an illusion, and the life we see thriving on this planet is indeed alive and kicking, we are obliged to conclude that organisms possess knowledge of the external realities they inhabit that is in some sense minimally correct. After all, a mountain goat unable to distinguish air from rock would very quickly fall off the mountain.

The arrival of human beings has improved this knowledge process in two unique, related ways: unlike other species, we are consciously aware of our knowledge, and thus are able to deliberately pursue it; and unlike other species, we can embody our knowledge in material technologies that reshape the world. To live in an environment is of course not only to receive from it but to give to it, and thus all organisms are in the business of remaking the world, if only in the subliminal sense of redistributing particles of living and nonliving matter from one place to another. But in human technology this organic contribution to the world has reached such proportions as to become a primary constituent of the world, and indeed our planet is increasingly becoming a product of human knowledge rather than natural selection. Since human understanding and its material expression in technology are of course consequences of the natural selection that resulted in humans, this humanization of our part of the universe through technology may be seen as natural selection or the process of evolution transcending itself. Like the goat,

we humans also know the difference between between air and rock; but unlike the goat, we build bridges between mountains so as not to fall off, or we jump off the mountain in space ships.

In some cases we construct technologies not for the purpose of directly improving our external material environment, but for the purpose of improving our knowledge of external reality (which of course sooner or later results in an alteration of material reality). Some of these information technologies, such as telescopes and microscopes, seek to improve our knowledge by enhancing our perception of the external world; others, such as computers, speed up our cognitive faculties themselves, allowing for rapid digestion of increased quantities of data; and still others, such as typewriters, books, and again computers, contribute to the growth of knowledge by widely disseminating our ideas and thus exposing them to many sources of testing and criticism. This paper will examine some of the consequences, intended and unintended, of such information technologies for the evolution of our knowledge, and, by extension, of ourselves, our world, and ultimately the universe. For human knowledge through the vehicle of human technology is a spearhead in a profound alteration of the heretofore blindly evolving, unforeseeing universe, a self-transcendence in which the undirected cosmos is beginning to turn itself inside out into a planned and deliberate existence. From this perspective, the radio telescope and electron microscope, the typewriter, xerox machine, and of course the computer -- devices which help generate and disseminate knowledge, which when embodied in other devices begin to reshape the universe -- work as the cutting edge of cosmic evolution.

Technology and Evolutionary Epistemology

Before considering the contribution of technology to the evolution of human knowledge, let us examine in a bit more detail the relationship between knowledge and evolution. The assessment of knowledge from an evolutionary standpoint, and of evolution from the standpoint of knowledge, has occupied such thinkers as Konrad Lorenz, Karl Popper, and most of all American psychologist Donald T. Campbell, who has termed this approach "evolutionary epistemology," and has compiled bibliographies of nearly 50 essays in this area in the past 100 years, and over 100 more in the past two decades.[1] One of Campbell's own chief contributions to the field has been his depiction of evolution as the development of increasingly vicarious, and thus error-prone but physically safe methods of obtaining knowledge about the environment. The primitive amoeba, for example, knows everything it knows of its environment by swimming through it or bumping into it -- a highly accurate yet dangerous technique that obliges the amoeba to come into physical contact with everything it knows. Vision, hearing, and modes of perception of more advanced organisms function as substitutes for physical contact in the gathering of knowledge, at once opening the door to a greater number of false reports (amoebas do not suffer optical illusions), yet bestowing upon their possessors a distance from the perceived object which increases maneuverability and safety. Campbell's analysis stops at the human deployment of thinking, culture, and science as similarly operating proxies for perception in the attainment of knowledge, but as we shortly shall see, technologies which extend our senses to remote parts of the universe and the subatomic realm are an equivalently crowning achievement in the evolution of increasingly vicarious knowledge receptors.

In addition to such literally biological functions of knowledge, evolutionary epistemology posits various analogies between the growth of living organisms and the growth of human ideas. Campbell, again, provides a compelling example[2], portraying the evolution of life and knowledge alike as an indirect, Darwinian, three-part process. To begin with, both new organisms and new ideas are initially generated independently of the environment in which they will perform or be applied. This separation of creation from environmental requirements is non-Lamarckian in biological terms, non-inductive in terms of the acquisition of knowledge. Next, biological and cognitive creations are both subjected to a confrontation with external reality, surviving only if they evince some degree of compatibility with the outside world. This winnowing process of natural selection is carried out by criticism and testing in the realm of science and human knowledge. Lastly, the survivors of the second stage must be retained in the bodies of life and knowledge, respectively, if the processes which created and selected these survivors are to be of any value. This objective is accomplished through mechanisms of heredity in the biological realm, and by media of dissemination in the world of knowledge. Information technologies, as we shall see, contribute to all three stages of the knowledge process, and indeed may be assessed as to which of the three stages -- generation, criticism, or dissemination of knowledge -- they make their most fundamental contribution. Technology, then, plays important roles both in the direct biological performance of knowledge (as an evolutionarily advanced substitute for in-person perception) and in the biological-like or evolutionary way in which knowledge itself develops.

Technology As an Embodiment of Ideas

Technologies purposely applied to the pursuit of knowledge are of course but a part of a larger class, technology in general, and thus we begin our examination of the technological contribution to the evolution of knowledge by looking at how all technology, informationally intended or otherwise, contributes to the growth of knowledge. The epistemic import even of a toothpick is significant, and becomes apparent when we inquire into the ontological status of technology, or simply ask, What is technology? Clearly, technology is something very special in the world, for it is neither like the clouds or the trees (unless the trees have been purposely planted), the natural realm of non-living and living material which humans had no hand in creating, nor the knowledge in our heads, human creations which though situated in the material substrates of our brains enjoy no material formulation in the world (to have knowledge of an automobile is not to have a miniature nuts-and-bolts car literally in one's head). Without technology, then, all the world (and perhaps the universe) is either material and non-human, or human and immaterial. Human beings themselves are of course the exception, and in rearranging the material of the external world to human specification, in giving material expression to incorporeal ideas, technology extends the human exception to the universe at large. Technology is thus material and mental, real atoms and molecules reconfigured by the magic wand of our intellect, substanceless conceptions brought to material life.

The implications of this technological intermingling of mind and matter are of obvious significance to many traditional philosophic arguments. The example of the active intrusion of the human mind into the material world provided by technology disputes one-sided materialist

or empiricist perspectives that view the mind as a mere passive recipient of the world's lessons, while the technological presupposition of already existent external material to be rearranged according to human ideas contradicts wholly subjectivist or idealist conceptions of the world as a complete product of the human mind with no independent existence. Strengthened and indeed literally substantiated by technology are interactionist models such Kant's, which view knowledge as representations of the external world shaped by the contours of our intellect. (Evolutionary theory also supports interactionist perspectives, positing an external reality that acts upon mindless organisms and thus must be independent of the mind, and accounting for innate knowledge as a genetically transmitted adaptation to prior environments.)[3]

But the technological enterprise as a whole not only has great significance for philosophies of knowledge, technology also has great impact on the growth of knowledge itself. For in embodying one or more human ideas, every technology provides a permanent record of this knowledge, an expression of human thought far more durable and therefore accessible than an immaterial conception. An automobile is thus a compendium of materially embodied ideas about combustion, alloys, hydraulics and of course travel, a quite literal incorporation of numerous theories in glass, rubber, and metal parts. Stepping back a bit, we can see that all the technologies ever produced by humans, from cave paintings to pyramids to pushcarts, form one huge, open-stack, unintended library of human knowledge throughout the ages, a panhistorical, transcultural grand Library of Congress accessible to anyone who recognizes it for what it is.

Moreover, despite its encyclopedic scope, this unintended library is quite selective in its holdings, admitting only those volumes whose embodied ideas have some degree of accuracy, or compatibility with external reality. Thus, not included in this library are automotive designs whose material embodiments exploded in the laboratory, flying machines that never got off the ground or crashed shortly after take-off at the turn of the century. In terms of the three stages in the development of knowledge discussed earlier, any technology that ever worked is an example of an idea that has survived the strongest criticism possible: a confrontation with material reality. Although the solutions to problems embodied in technologies are never perfect or exclusive, they necessarily are minimally accurate, i.e., cannot be totally incorrect.

In this sense, then, all technologies, regardless of their intended purpose or specific design, are cognitive or instrumental in the growth of knowledge. Thus, although the purpose of the automobile -- transportation -- has little or nothing directly to do with the development of knowledge, the physical structure of the automobile, as we have seen, nonetheless contributes to our knowledge by materially embodying diverse and minimally accurate ideas. In some cases, however, technologies not only embody knowledge in their material structures, but are deliberately designed to help generate and disseminate other knowledge in their performance. A telescope, for example, not only incorporates theories of optics, lens making, etc. in its physical components, but helps increase our knowledge of the cosmos when these physical components are pointed at the stars. In as much as such technologies give a "double-assist" to our cognition, with knowledge itself rather than, say, transportation or teeth cleaning

the purpose of their performance, they may be considered "meta-cognitive" technologies, or objects of cognition whose object is to further cognition. As may be obvious, these information-intended technologies have played much a more active, indeed explosive, role in the growth of human knowledge than the more passive record-keeping contribution of technology in general. We will examine the operation of four classes of meta-cognitive or information technologies in the evolution of knowledge: extenders of our perception of the external world, e.g., telescopes and microscopes; enhancers of our internal cognitive processes, e.g., computers; disseminators of information via high levels of abstraction, e.g., spoken and written languages; disseminators of information via high levels of realism, e.g. photography and video. In terms of the three-stage process of knowledge development, the first two classes contribute primarily to the initial generative phase of knowledge, the second two to the phases of criticism and dissemination.

Telescopes, Microscopes, and Extenders of Experience

According to Kant, knowledge results from the digestion of external experience by our cognitive capacities. The absence of either component, external or internal, renders knowledge acquisition impossible: unconditioned experience of the external world, even were it possible, would be utterly unintelligible without a cognitive filter to sort it out; and the operation of cognitive faculties on something other than external experience becomes a self-reflexive, chimerical exercise, much like mirrors directed at mirrors, or a video camera focused on a screen displaying the image produced by the video camera. Technologies such as telescopes and microscopes help the generation of knowledge by

augmenting the external experience component -- by increasing our food for thought, literally, through extension of our awareness to areas which, on the basis of our naked senses, were beyond our capacity to experience and thus to comprehend.

In some cases the extension is more radical than in others. Thus, the telescope brings us into better contact with stars and galaxies which in a limited, highly distorted way are already perceptible to our naked eyes, while the microscope's discovery of microorganisms calls forth a realm utterly invisible to unaided observation. In all cases of such technological extension, however, events whose size or distance from the human observer places them beyond the effective pale of our perception are cast in dimensions accessible to our senses and thus potentially digestible by our intellect. The act of extension, then, is an act of transformation, in which aspects of the universe bordering on the infinite and the infinitesimal are transformed into human proportions; or perhaps the transformation works the other way, perhaps it is we, who, with telescopes and microscopes in our eyes, grow into the dimensions of the universe. Either way, the result is that aspects of existence which we were formerly blind and deaf to (or at least myopic to) are opened to our scrutiny, packaged in a form graspable by our intellect. (The benefit is enjoyed by all aspects of our cognition, not only the purely intellectual. E.H. Gombrich, for example, reminds us that single snowflakes are nondescript dabs of white until magnification calls forth their intricate latticework and beauty[4] -- i.e., transforms them into proportions that can engage our aesthetic faculties.) In terms of the evolution of our knowledge of the external world, telescopes and microscopes put the far and hidden reaches of the universe in

our cognitive backyard. The "disproportion of man" to the cosmos which so awed Pascal[4a] is both revealed and repaired.

The question inevitably arises as to what extent the observations of events through technology pertain to the events as they are, independent of the technology, and to what extent the observations are artifacts or products of the technology. Aristotle's preference for the testimony of our naked senses over technology was probably warranted by the poor quality of experience-extending devices in ancient times (though Aristotle's view made life quite difficult for Galileo)[5], and of course all technologies, even the most advanced, necessarily function with some degree of noise or imperfection. But the dichotomy of an artificial world served up by our technologies versus a natural, real world provided by our biological senses disappears when we recall Kant's insistence that the world perceived through our senses is not, and cannot, be the world "as it is," but rather the world as molded by our senses. Thus, the colors that we see are part of a much larger band of radiation edited by the structures of our vision. In this light, the natural perceived world has no more ontological or epistemological legitimacy than than the world revealed by technology: both are representations or reconstructions of reality, and the fact that one is accomplished through living tissue and the other through glass and plastic confers no necessary advantage or proximity to reality on either. Of course, our biological structures have been tested in interactions with external reality for millions of years, and thus we must credit them with at least the minimal degree of accuracy or correspondence to external reality necessary for survival. But there is no reason to suppose that, with the understanding we already have of our biological senses and the principles of perception, we are unable to build technologies that operate with at least equivalent

accuracy in domains beyond the reach of our unaided perception.

But granting the acceptability of technologically engendered perceptions, we encounter yet another possible hazard arising from the technologicial augmentation of experience. Even here on Planet Earth, in our everyday naked perception, we experience many phenomena which elude our satisfactory understanding (e.g., magnetism) -- we indeed have far more experience than our cognition could possibly handle. Now when we add to this already crowded table the bounty of our technological extensions, do we not run the risk of overwhelming the capacities of our intellect, of placing so much food on the cognitive table that the whole structure collapses? This experience overload would indeed be a serious problem, were it not for technologies specifically designed to boost our native powers of cognitive digestion, and turn the glut of experience into an advantage.

Computers and the Enhancement of Cognitive Processing

As suggested above, even at the dawn of our humanity we probably experienced far more than our cognitive processes could handle. Numbers were an early technique for dealing with this problem (according to Alexander Marshack, a very early technique, perhaps 300,000 years old [6]): counting the numbers of animals obtained in hunts allowed hunters to compare the success of their forays, i.e., process the raw results of the hunts into a pattern which might serve as a basis for improvement of hunting efficiency. In general, the abstraction of real events into numbers facilitates their classification and sorting, which in turn permits the cognitive manipulation of these events into generalities and

theories. The invention of the place-holder, zero, was especially significant in this regard, permitting the development of increasingly complex computations that manipulated more and more real experiences in less and less time through multiplication, algebra, and eventually calculus, the requisite of Newton's cosmology. (Indeed, the failure of the Roman Empire to achieve an industrial culture, despite its propensity for engineering and technological gadgetry, may have been due to the clumsiness of its number system, which, lacking the place-holder, was incapable even of multiplication.)

Computers do for numbers what numbers do for real experiences: they greatly speed the sorting and classification of numerical information. The result of this speed-up of the speed-up of experience processing is that our cognitive capacities are given tractable summaries of huge quantities of experience, enabling us to get a cognitive fix on much broader and more detailed aspects of existence. Science has long sought unifying theories that tie together diverse facets of reality, but the limited quantities of experience capable of being processed by our unaided cognitive faculties have hampered this quest, and rendered such grand theories as have been produced more the result of bald speculation than empirical evidence. Computation of data at the speed of light changes this imbalance, and allows us a big picture grounded in a big piece of external reality. In this sense, then, the computer not only complements the telescope, but is analogous to it in its performance: the telescope reduces the dimensions of the universe to human proportions; the computer reduces the numerosity of the universe, the sheer quantity of vast expanse and myriad detail, to humanly graspable units. In pre-digesting vast amounts of experience, computers allow

our cognitive faculties to bite off much larger portions of external reality than they could chew on their own.

The benefits of such expansion have already been felt in most areas of science.[7] But perhaps the most dramatic indication of the possible effect of computers on the growth of knowledge is suggested by the recollection that Isaac Newton spent the vast majority of his working time not in the generation of new ideas but in the laborious hand-written computation of his equations.[8] How might the course of science and history have run had Newton the services of even a small pocket calculator? What will result from geniuses of Newton's calibre free to devote the lion's share of their intellect to creation rather than computation?

The mention of pocket calculators, however, brings to the fore a fear frequently voiced by some educators that computers may be counter-evolutionary or destructive of the human intellect, in that they obsolesce much of our memories and arithmetic ability.[9] This fear in one form or another is actually very old, and was raised by Socrates, who in the Phaedrus warns that writing will result in the atrophy of memory and the end of learning through dialogue[10] (fortunately or unfortunately for Socrates, his pupil Plato troubled to write this warning down). Such misgivings would seem to have about as much validity for computers as they have had for writing: Socrates was not incorrect, in the immediate sense, in that access to written or any recorded material may indeed dull the rote part of our memory, and one certainly cannot engage a written page in two-way discussion; but he of course was wildly off the mark in the longer run, for writing gives

us transpersonal, even transcultural memories, which have resulted in exponentially greater exchanges of information than ever could have occurred, or do occur, in purely oral cultures. In the case of computers, is not the loss of the ability to find square roots, or even to perform complex multiplications by hand, well worth the enormous gains in mathematical and communication power at the cutting edge of science and knowledge (gains which incidentally include the capacity for immediate written dialogue through print on computer screens)? And even in the absurdly unlikely event that worse came to worse, with (a) no human able to do any mathematical task at all without the aid of computers, and (b) all computers and all knowledge of how to build computers somehow disappearing, would there be any compelling reason to suppose that humans, having developed our number system (and indeed many others) in far more primitive surroundings, would be unable to develop and learn the operations of mathematics again?

No evolutionary structure, whether technological or biological, is ever an unmixed blessing; rather, structures qualify as beneficial if their performances result in a net gain of some sort for the organisms they serve. The technological extension of sensory experience by telescopes and microscopes and of cognitive processing by computers performs such a service for human knowledge, covering both of the bases, external and internal, of knowledge generation. But the growth of knowledge, as we have seen, entails not only the initial generation of ideas or representations of reality, but their subsequent criticism (winnowing out) and dissemination. Moreover, whereas the initial generation of an idea may be, and indeed at ultimate origin must be, a solitary activity, criticism and dissemination are social or communicative

-- dissemination by definition, criticism in practice, since the criticism of one's own ideas is at very least psychologically suspect. The technological contribution to the criticism and dissemination of knowledge thus takes a form different from the initial technological detection and processing of experience, the goal of technological communication of knowledge being not the production of representations of reality, but the transmission of such representations, regardless of their truthfulness (correspondence to reality), to as many people as possible as accurately as possible. These two objectives -- plurality and accuracy -- are not always compatible, and have been sought through two techniques, abstraction and replication, that we now consider.

Speech, Writing, and Communication Through Abstraction

Which medium do you think offers more accurate transmission of information: speech or photography? The question cannot be answered without reference to the nature of the information or representation being transmitted. If we wished to convey the size and ferocity of a lion we saw lurking in the savannah yesterday, a photograph would obviously be more specifically accurate. On the other hand, if we wished to communicate an abstract concept such as evolutionary epistemology, or the notion of "concept" itself, a photograph would not only be less preferrable but impossible -- speech is the only one of the two media capable of transmitting information about such intangibles. We thus get an inkling of the four-edged complexity of the communications environment: two classes of representations, of external reality and of abstractions, communicated by two techniques, replication and abstraction. Moreover, media vary not only in the accuracy of communication, in large part a function of the match between representation and

technique, but in how far and wide from the source they are able to transmit their information.

How did such a multi-faceted communications system come to be? There are two things we know with some assurance: (1) that external reality existed before abstract concepts as a possible object of representation (animals perceive external reality, but presumably do not create abstract concepts), and (b) that the highly abstracting medium of spoken language was the first major mode of human communication. Our media thus seem to have arisen in a mismatch of abstract technique (speech) applied to transmission of representations of tangible, external reality, which suggests the following scenario of the origins and subsequent development of communications systems: The initial function of speech was the transmission of information about external reality. In a technologically primitive world, lacking such niceties as tape recorders, cameras, and even paper, the only way of transmitting representations of external reality, or transporting them from their source, was by translating them into abstract symbols (words) which were conveniently portable but bore no natural connection whatsoever to the realities they ultimately described (the word "lion" bears no resemblance to any aspect of a real lion; onomatopoeia would be a trivial exception). In this early context, the distortion of abstraction, or sacrifice of accuracy, was the price paid for the transmission across space and time of any information at all about the tangible world. Eventually, however, the abstract vehicle of speech encouraged the development of a whole new class of objects of communication: representations of abstractions themselves, entities entirely of human creation with no tangible existence in the external world to begin with. (Abstractions of course

could have existed before language, but they would have served little purpose, being virtually incommunicable in a non-linguistic environment). Although the word "epistemology" bears no closer resemblance to the concept epistemology than the word "lion" does to the object lion, there is no conceivably less distortive or more accurate way of communicating concepts (short of mental telepathy), and thus abstract media and abstract concepts have flourished in a mutually reinforcing relationship that has made abstraction both a central vehicle and object of human cognition. Indeed, the situation of abstract media -- first speech and then speech and writing -- being the only communication game in town, the only way of transmitting information about external reality as well as abstractions, persisted until the invention of replicative photography in the 19th century.

If the above scenario is correct, then speech has had a doubly enabling role in the evolution of knowledge, and thus of ourselves, providing initially the only means of communication about external reality, and eliciting a new humanly created realm of abstract concepts. This dual impact has been heightened by writing, especially the alphabet, which as Harold Innis and Marshall McLuhan have pointed out made possible many aspects of classic civilization, including the early rise of science and of monotheism;[11] and later by the printing press, which as again Innis and McLuhan have stressed transformed the medieval into the modern world by encouraging such developments as the Scientific Revolution, the Protestant Reformation, and the rise of national states.[12] Writing of course improves upon speaking not only by providing permanency, which greatly increases the range of dissemination, but by eliminating the distortion that occurs every time a message is respoken: written information, after all, need be transmitted only once to be received

throughout all eternity. That writing is the last word in the communication of much of our knowledge is demonstrated in the growing presence, as indicated above, of printed exchanges on computer screens. Indeed, print-outs have always been an integral part of computers, as writing has been a part of the electronic revolution since its inception, in the words on telegrams and the reading of books encouraged by electric lighting.[13]

But as also suggested above, the abstract hegemony of speech, writing, and print leaves the communication of much of the basis of human knowledge out in the cold; indeed, these media make the whole of external reality a second class citizen in communication. For the external world to receive its due, knowledge had to progress to the point where humans could invent a whole new genre of media, beginning with the development of photography 150 years ago.

Photography, Electricity, and the Replication of External Reality

Complete replication of an original is in principle impossible and self-defeating, since the duplicate obviously cannot capture, and indeed serves to destroy, the uniqueness of the original. The goal of replication is thus always partial, and usually amounts to the reproduction of salient aspects of the original as accurately as possible.

Pre-alphabetic pictographic systems made some attempt at replication of visual reality, but ultimately failed to survive due to poor performance both as replicators and disseminators. (Pictographic systems, which require a different symbol for each word or object recorded, are much more

cumbersome to learn and use than phonetic alphabets such as ours which operates with 26 symbols. The survival of Chinese ideograms, which are part pictographic and part phonetic, is a partial exception.) Paintings of course also attempted to replicate the visual world, but the critical breakthrough came with the photograph and its offspring.

Photography is special because it is, to paraphrase André Bazin, free of the original sin of subjectivity[14] -- that is, it captures the world without the inevitably abstracting intervention of human mentality present in all painting, and of course in all verbal and written descriptions of external reality. The aspects of the world conveyed in the immaculate conception of the photograph are thus as close to external reality as what we see of those aspects with our naked eyes or through telescopes and microscopes. Moreover, although the first photographs accurately captured only one feature of external reality, visual shape, subsequent developments in photography restored motion, synchronized sound, color, and with the development of holography in 1949, the dimension of depth to the communicated representation.[15] This widening of the range of external reality whose representations are transmittable without abstraction has assisted not only the criticism and dissemination of these representations, but their very generation, for the life-like photographic image of external reality may serve as a substitute for the human perception of external reality in the initial encounter of the external world and human cognition that generates representations or knowledge of reality (the photographs produced by space probes would be one such case).

At the same time, the infusion of electricity (and electro-magnetic waves) into communication has resulted not only in the interactive,

instantaneous, simultaneous transmission of printed information, but the immediate and simultaneous transmission to millions of people of non-abstract images and sounds as well. Indeed, with the hook-up of increasingly portable computer and video systems, we are rapidly approaching a time when anyone, at any hour, from any place in world, will have instant access to all the knowledge possessed by humanity. This would obviously constitute a maximally optimal environment for criticism and dissemination of knowledge, and its generation as well.

Thus in the past 150 years the electro-chemical revolution has restored an empirical presence lacking in the communication of representations since the origin of communications and humanity in speech.

Cognitive Evolution As Cosmic Evolution

In sum, then, technology contributes to the growth of human knowledge in five distinct, though overlapping, ways: (a) all technologies are material embodiments and thus more or less durable records of ideas that have survived some test with external reality; (b) telescopes, microscopes, and similar technologies extend our external experience, and thus the generation of knowledge in areas inaccessible to our naked senses; (c) computers enhance the operation of our internal cognitive faculties themselves, fostering the generation of knowledge from huge quantities of experience which might otherwise have overwhelmed our unaided mental capacities; (d) speech, writing, and similar media facilitate the criticism and dissemination of knowledge by transmitting information

or representations via abstraction, a process especially hospitable to the communication of abstract concepts, and perhaps even responsible for their existence; (d) photographic and image-and-sound producing media transmit representations of external reality with little or no abstraction, enabling widespread criticism and dissemination of representations with very high degrees of correspondence to aspects of external reality as directly perceived by our senses. The technological contribution to knowledge thus covers all necessary cognitive bases, external and internal, abstract and sensational.

As suggested earlier, the technological contribution to, and to some extent constitution of, human knowledge has consequences that go well beyond human knowledge per se, for our knowledge is surely not a closed or self-contained system. To the contrary, human knowledge or understanding and organization of the external environment appears to stand both at the summit of prior cosmic evolution, and the doorway to the future of the universe. Whether we think (with, for example, Wiener) that human knowledge is ultimately but a hopeless finger in the dyke against entropy,[16] or (with, for example, Prigogine) that even non-living matter displays some of the order-through-fluctuation characteristics of the knowledge process[17] (I tend to agree with Prigogine), we can see that knowledge has emerged from and transcended a much dumber, undirected universe. When we further consider that the implementation of knowledge in technology quite literally and materially alters the external world, we can begin to see how existence may be increasingly shaped by the expression of knowledge in technology. Such cosmic implications of technology have been appreciated by several major philosophers, such as Marx and Heidegger, and by several minor figures, including Friedrich

Dessauer,[18] but have generally been unaddressed by the intellectual currents of our time.

The decisive effect of human knowledge and technology is that, although they themselves are surely not free of unintended consequences and encounters with unforeseen elements of the environment, they inject an element of direction, deliberation, planning into a naturally-selective universe which presumably previously had none. Human control of course does not mean that natural selection or evolution will stop or end, but rather that it will be humanly proposed or derived. The situation seems much like a freeze frame in a motion picture, where although the film keeps moving through the projector and the motion picture process continues, one image appears in all the moving frames and thus looks frozen on the screen. In the technological projection on the cosmic screen, that image will be human. We might say that, through the expression of human knowledge in technology, the future of the universe lies in the human mind, and thus in the information technologies that assist it.

Notes

[1] Campbell, "Evolutionary Epistemology" in The Philosophy of Karl Popper, ed. P.A. Schilpp (LaSalle, IL: Open Court, 1974), pp. 413-463; "Evolutionary Epistemology: Partial Supplementary Bibliography," distributed at the First International Convocation of the Open Society and Its Friends, New York City, November 1982 (chair: P. Levinson, Fairleigh Dickinson University, Teaneck, NJ). Representative works by Lorenz and Popper: Lorenz, "Kant's doctrine of the a priori in the light of contemporary biology," (first published 1941) trans. D.T. Campbell in Konrad Lorenz: The Man and His Ideas, ed. R.I. Evans (New York: Harcourt Brace Jovanovich, 1975), pp. 181-217; Popper, Objective Knowledge (New York: Oxford, 1972).

[2] "Unjustified Variation and Selective Retention in Scientific Discovery" in Studies in the Philosophy of Biology, eds. F.J. Ayala & T. Dobzhansky (Berkeley,CA: Univ. of California, 1974), pp. 179-186.

[3] The relevance of technology to philosophy is explored in my "What Technology Can Teach Philosophy" in In Pursuit of Truth: Essays on the Philosophy of Karl Popper, ed. P. Levinson (Atlantic Highlands, NJ: Humanities, 1982), pp. 157-175. These and most of the other themes discussed in the present essay are more fully developed in my Mind at Large: Knowing in the Technological Age, forthcoming.

[4] The Sense of Order (Ithaca, NY: Cornell, 1979), p. 9.

[4a] Blaise Pascal, Pensées, trans. H.F. Stewart (New York: Pantheon, 1950), pp. 18-31.

[5] Aristotle held that although natural and artificial processes were capable of error (Physica, II, 8), one natural process, perception of primary qualities (e.g. color) through the senses, "is never in error or admits the least possible amount of falsehood (de Anima, III, 3), The Pocket Aristotle, ed. J.D. Kaplan (New York: Pocket, 1958), pp. 44, 91. See also Paul Feyerabend, Against Method (London: New Left, 1975), ch. 10.

[6] Discussed in B. Rensberger, "The World's Oldest Works of Art," The New York Times Magazine, 21 May 1978, pp. 26-29 ff; see Marshack, The Roots of Civilization (New York: McGraw-Hill, 1972), for examination of the development of mathematics in more recent periods of the Pleistocene.

[7] See W.O. Baker et al., "Computers and Research" in Electronics: The Continuing Revolution, eds. P.H. Abelson & A.L. Hammond (Washington, DC: AAAS, 1977), pp. 56-61 for a preliminary survey.

Notes

[8] Indeed, Newton was disdainful of a rival's claim to have discovered the law of gravity on the grounds that "Dr. [Robert] Hook could not perform that which he pretended to: let him give demonstrations of it. I know he hath not geometry enough to do it," Frank E. Manuel, Portrait of Isaac Newton (Cambridge, MA: Belknap, 1968), pp. 152, 422. For an indication of the importance of computer programs in the calculation of equations in current theoretical physics, and a discussion of the furor that erupted at the California Institute of Technology over the possible commericial exploitation of such a program, see G. Kolata,"Caltech Torn by Dispute Over Software, " Science, 27 May 1983, pp. 932-4.

[9] J.W. Wyatt et al. report in "The Status of Hand-Held Calculator Use in School," Phi Delta Kappan, November 1979, pp. 217-8, that 43% of the teachers they surveyed thought that pocket calculators would diminish the memory and mathematical ability of children. The authors also report that more than 100 studies on the effects of pocket calculators show no immediate adverse results (the technology was too recent for longitudinal studies).

[10] The Works of Plato, trans. B. Jowett, ed. I. Edman (New York: Modern, 1928), p. 324.

[11] Representative works: Innis, Empire and Communications (Toronto: Univ. of Toronto, 1950/1972), The Bias of Communication (Toronto: Univ. of Toronto, 1951/1964); McLuhan, The Gutenberg Galaxy (New York: Mentor, 1962), Understanding Media (New York: Mentor: 1964). See also Eric Havelock, Preface to Plato (Cambridge, MA: Harvard Univ, 1963), and The Literate Revolution in Greece and Its Cultural Consequences (Princeton: Princeton Univ., 1982).

[12] See also E. Eisenstein, The Printing Press As an Agent of Change (New York: Cambridge Univ., 1979).

[13] David de Hahn suggests that "electric lighting did more to improve the habit of reading books than anything before it," Antique Household Gadgets and Appliances (Woodbury, NY: Barron's, 1977), p. 121.

[14] What Is Cinema?, trans. and ed. H. Gray (Berkeley, CA: Univ. of California, 1971), pp. 12-14.

[15] The evolution of communications media towards fuller and more accurate replication of "pre-technological" reality is considered in detail in my "Human Replay: A Theory of the Evolution of Media," Ph.D. diss., New York University, 1979.

[16] E.g., Norbert Wiener, The Human Use of Human Beings (New York: Avon: 1950/1967), p.66.

[17] E.g., R.B. Tucker, "Interview with Ilya Prigogine," Omni, May 1983, pp. 84 ff. See Erich Jantsch, ed. The Evolutionary Vision (Boulder, CO: Westview, 1981), for a fuller discussion of these and related themes.

Notes

[18] See Daniel Bell, "Technology, Nature, and Society" in The Frontiers of Knowledge (no ed.) (Garden City, NY: Doubleday, 1975), pp. 28-78 for a discussion of Marx in this regard; Michael Zimmerman, "Technological Culture and the End of Philosophy" in Research in Philosophy and Technology, Vol. 2, ed. P. Durbin (Greenwich, CT: JAI, 1979), pp. 137-145 for an examination of Heidegger on technology; and Friedrich Dessauer, Philosophie der Technik; Das Problem der Realisierung (Bonn: Cohen, 1927), (Part II trans. by C. Mitcham as "Technology in Its Proper Sphere" in Philosophy and Technology, eds. C. Mitcham & R. Mackey [New York: Free Press, 1972], pp. 317-334, 375-377). See also my "What Technology Can Teach Philosophy" and Mind at Large, op. cit.